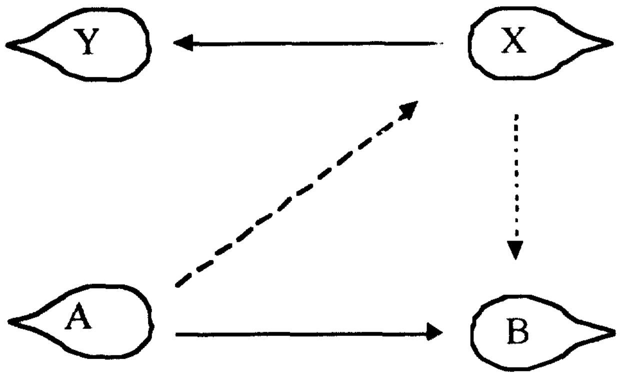
to receiver to the one single best path, thus reducing the multipath distortion of the signal recovered by the receiver. This technique of reducing interference is quite effective when both the transmitter and receiver have directional antennas under the control of a diversity algorithm.

Interference Considerations When Directional Antennas Are Prevalent

From the discussion in the previous paragraph, Motorola concludes that directional antennas will be prevalent in the unlicensed bands at 5 GHz. When directional antennas are prevalent, the LBT etiquette results discussed above for 2 GHz applications, where directional antennas are assumed not be as prevalent, are no longer valid. Two significant issues are apparent;

1. If an LBT rule similar to the LBT etiquette rule at 2 GHz was applied to the 5 GHz band, many transmitters that are not actually potential sources of interference will be required to defer. This is a highly undesirable result.
2. Because of the anticipated use of diversity techniques in communications receivers at 5 GHz, interference avoidance will be a natural byproduct of the radio technology. The utility of diversity in avoiding interference is expected to be far more effective at 5 GHz than the factor of a few dB gained in the UPCS bands at 2 GHz utilizing the LBT rule with omni antennas.

The issue of needless deferral is discussed with the benefit of Figure A8. This figure illustrates the scenario where a potential interferer, X, and the other transceivers have gain antennas, as depicted by the simple directional pattern icons.



If X were omni, it would not defer to A since the signal from A would be too low. Since X is directional, and pointing in the general direction of A, X will defer to A. However, since X and B are directional, the deferral yields no utility, i.e., X would not have interfered with B even if X had not deferred and transmitted its signal to Y

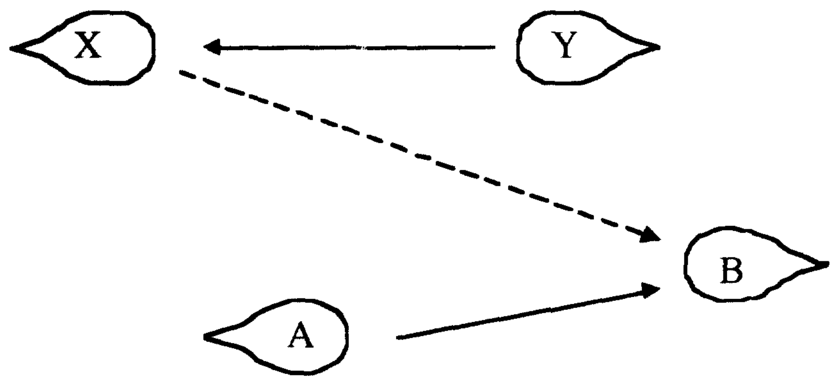
Diminished Utility of LBT Etiquette with Directional Antennas

Figure A8

From the geometry of this example, it is apparent that compared to a scenario where all units have omni antennas, X is more likely to be required to defer to a transmission from A because of the directivity of both A and X antennas. However, because both X and B have directional antennas, X is much less likely to interfere with B's reception of a signal from A.

An important conclusion can be drawn from this example:
Transceivers with directional antennas will be required by an LBT to defer in situations were their potential transmission poise no interference threat. Whereas in the 1.9 and 2.39 GHz UPCS bands, deferrals, in the main, were useful in eliminating sources of interference, the prevalent use of directional antennas at 5 GHz will lead to many useless deferrals, thus wasting bandwidth and causing delays. With the prevalent use of directional antennas, the LBT etiquette itself becomes a new source of interference.

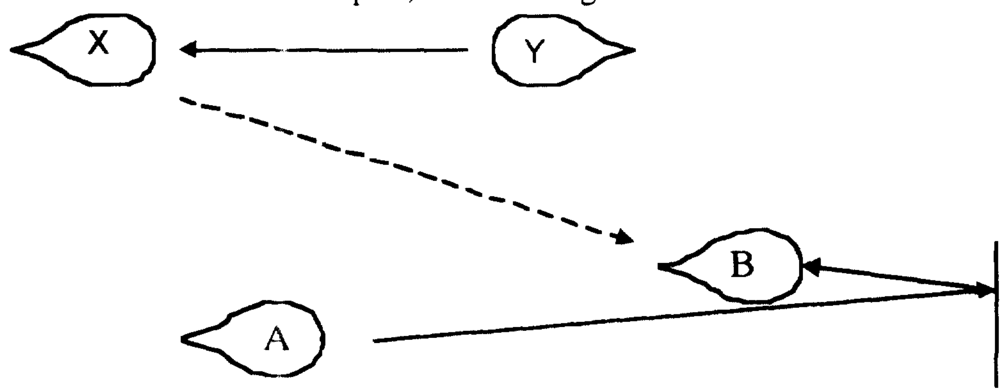
The final scenario concludes that antenna diversity techniques reduce the potential for interference dramatically. Consider, for example, the situation where B, the receiver of packets from A, is receiving interference from X as shown in Figure A9a.



B Receives Interference from X

Figure A9a

Here B has multiple antennas and the ability to use the antenna that provides the best performance, i.e., diversity. As shown in Figure A9b, B uses an antenna that receives a reflection of the signal from A rather that the direct path, thus reducing interference from X.



B Avoids Interference from X with Antenna Diversity

Figure A9b

From these examples. Motorola wishes to convey the conclusion that since gain antennas will be very common and a virtual necessity to achieve the FCC's goal of high data rate communications at 5 GHz, the LBT aspect of a spectrum etiquette is of less utility than in the UPCS bands of 1.9 and 2.39 GHz. Moreover, the use of a LBT rule in a spectrum etiquette at 5 GHz could significantly burden the use of directional antennas because of the increase in the rate of non-beneficial deferrals. This result would undercut the FCC's goal of promoting products and systems incorporating higher data rate communications.

Appendix B- Paired Frequency Option

Summary

Paired frequency operation is highly desirable in some system applications. Cellular radio systems, for instance, use paired frequency operation in order to achieve both product cost and spectral efficiency advantages. By paired frequency operation we mean the frequency plan whereby one subband is used for base (access point) transmissions and another is used for mobile transmissions as illustrated in Figure B1.

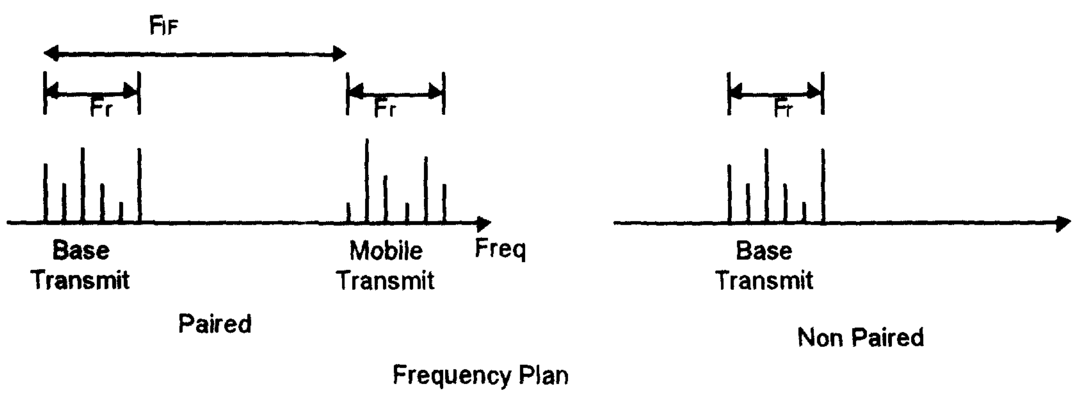


Figure B1

Within the context of the current 5 GHz unlicensed band NPRM, both the base and mobile transmit bands might be located in either the 5.2 or the 5.8 GHz segments. Or possibly, one subband might be at 5.2 and the other at 5.8 GHz.

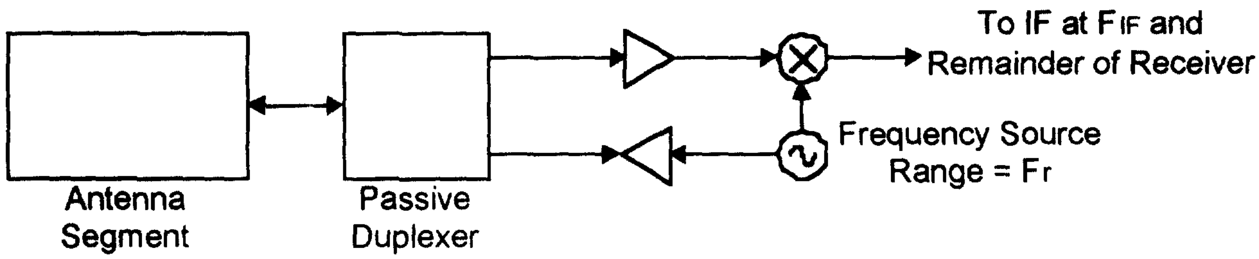
As discussed below. the fundamental property of LBT compliance, that a transceiver monitor an RF channel before it uses that channel for an RF transmission, is incompatible with the low cost potential of the paired frequency option.

Discussion

Utilization of the paired frequency option has two potential advantages:

1. Transceiver Cost.

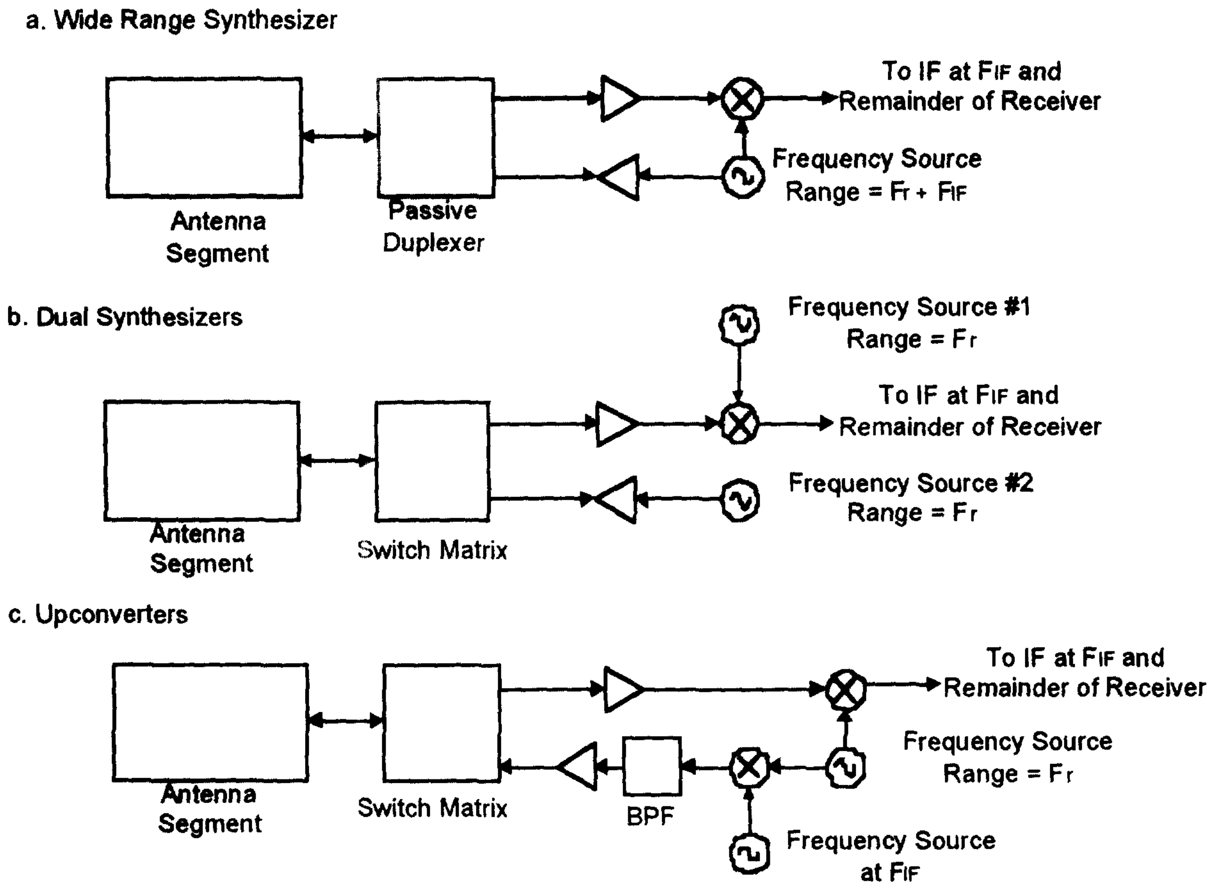
A paired channel radio can often be designed to utilize just one relatively narrowband synthesized frequency source that functions as a local oscillator during receive and as a carrier source during transmit, as illustrated in Figure B2.



Block Diagram of Transceiver with one Frequency Source

Figure B2

In doing so, the cost and complications associated with either, wide range synthesized frequency sources, or upconverters (with bandpass filters), or dual synthesized frequency sources, as illustrated in Figure B3, can be avoided.

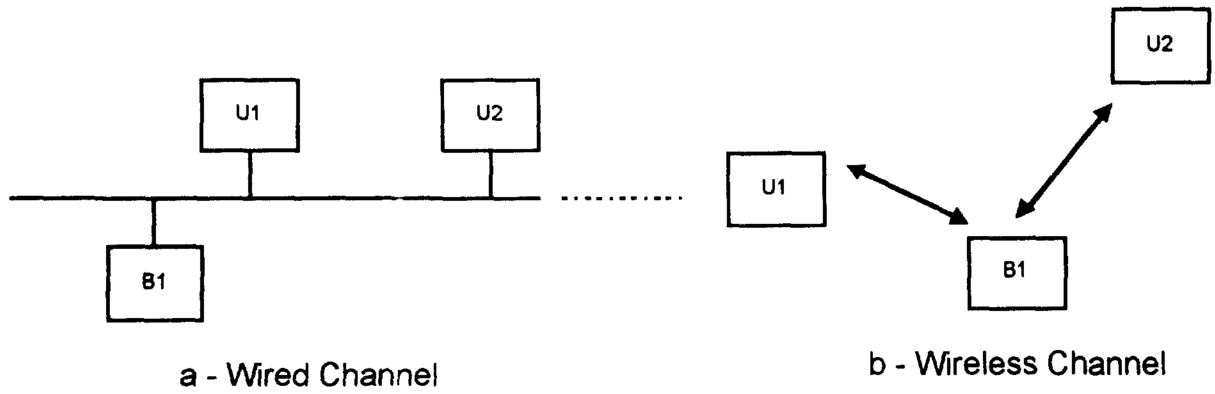


Hardware Options to Paired Channel Radio Designs
Figure B3

In alternative "a", a synthesizer with a wide frequency range allows the receiver to be tuned to either the transmit frequency or the receive frequency. The wide tuning range of such a synthesizer may represent a significant cost burden as well as presenting difficulties in switching rapidly between receive and transmit modes. Alternative "b" has the obvious cost, size and power consumption burden of requiring two synthesizers. In alternative "c", the second frequency source many not actually be a synthesizer, however, this configuration requires frequency upconversion . Upconversion is a complication in terms of filtering and amplifier requirements, thus impacting cost, size and power consumption. In cost sensitive consumer markets, these factors can have considerable significance.

2. System capacity and spectral efficiency

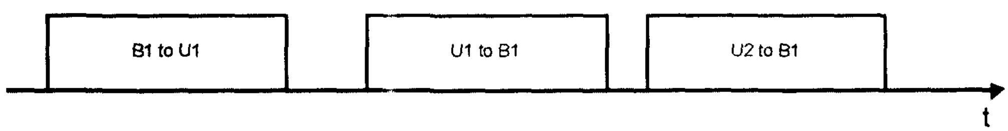
Consider an operational deployment of a base (B1) and several user terminals (U1, U2, ...) utilizing a communications channel as in Figure B4.



System Configurations

Figure B4

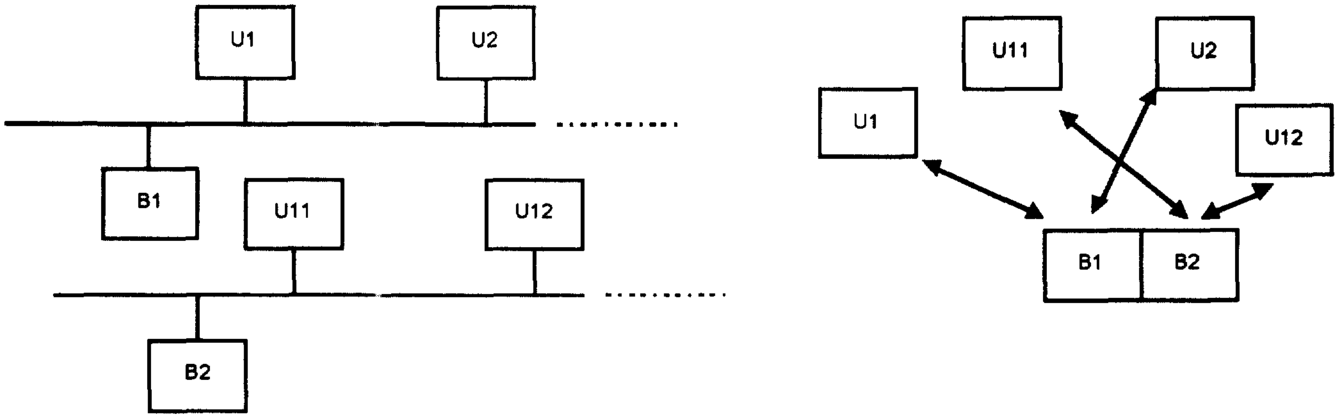
Whether that channel is wired or wireless, asynchronous communications traffic would generally occur as asynchronous data packets as depicted in Figure B5.



Exemplar Packet Sequence

Figure B5

As system traffic increases, an additional channel may be added as depicted in Figure B6.

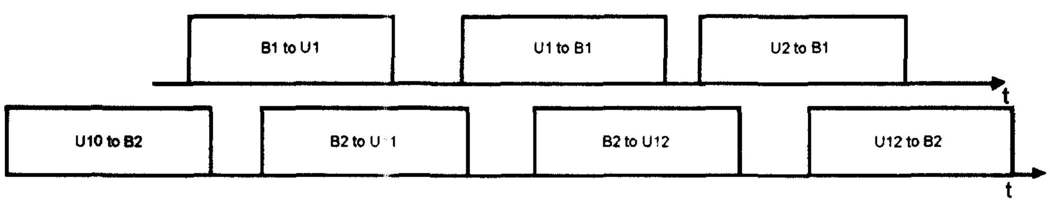


a - Wired Channels b - Wireless Channels

System Configurations

Figure B6

Assuming that the channels are wired, an exemplar communications traffic pattern is depicted in Figure B7.



Exemplar Packet Sequence
In a wired channel the capacity is doubled

Figure B7

Next consider the wireless portion of Figure B 6. If, the two wireless RF channels are separated by just a few number of channels (for example, 50 to 100 MHz at 25 MHz per channel) a receiver operating on channel #1 (B1, U1, U2, ...) would be vulnerable to desensitization from a transmission on channel #2 (B2, U10, U11, ...). As shown in Figure B8, B1 would not be able to receive a signal if B2 was transmitting and vice versa.

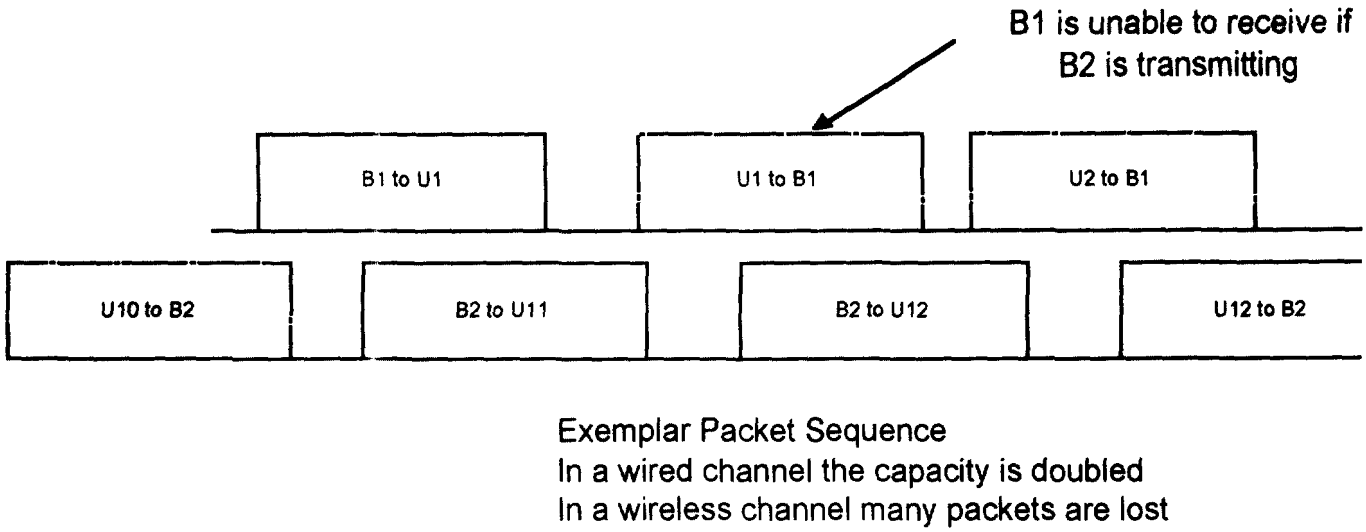


Figure B8

The reason for this is that if B1 and B2 are essentially collocated, then it may be beyond practical limits to provide enough RF isolation to prevent the transmitter of B1 from desensitizing the receiver of B2 and vice versa.

With paired frequency operation, bases transmit in one frequency subband and user units or mobiles transmit in another. Subband frequency planning is such that duplexer isolation is practical, so that B1 can receive while B2 is transmitting.

Conclusion

Thus, it is apparent that the paired frequency option has practical potential benefits for commercial applications. Unfortunately, an LBT etiquette would require the cost benefits of a paired frequency system configuration to be compromised in order to achieve the potential spectral efficiency gains. This is therefore another reason why Motorola recommends that the Commission not require an LBT Rule in the 5 GHz unlicensed band.

Appendix C- Power and Antenna Gain

Motorola recommends that the transmitter output power, rather than the EIRP, be regulated by the FCC rules and that antennas with up to 23 dB of gain be allowed. Motorola believes that this form of specification will actually lead to less harmful interference than an EIRP limit and will also offer sufficient range under high data rate applications in the 5 GHz unlicensed band.

The rationale for this recommendation is based on the consideration of the cumulative interference potential of many transmitters and the potential interference profile of an isolated radiator.

A. Many transmitters.

In order to understand the cumulative interference potential of many transmitters with gain antennas, consider a cluster of such unlicensed transmitters, located within a sphere of radius, r. The direction of the gain antennas is randomly distributed. The total number of transmitters, N, is much larger than the maximum antenna gain (in numeric value, not dB) of any one of the transmitters. Now consider an observer on the surface of a larger sphere having the same origin as the small sphere, but having a much larger radius, R, i.e., R is >>r. Under these conditions, no one transmitter will have a dominant effect on the signal power density at any point on the surface of the larger sphere and because of the averaging effect of a large number of transmitters, there will be very little variation in the observed power density across the surface of the larger sphere. The total power radiated by the sum of all N transmitters, Pt, is N times the power of each or,

$P_t = N*P$.

The power density, Pd, (RF power per unit area) radiating through the surface of the larger sphere is

$P_d = P_t/(4*Pi*R^2)$,

which is independent of the gain of the individual antennas as long as the maximum gain of any of the antennas is much less than the total number of radiators in the smaller sphere. Thus, when one is considering the cumulative effect of many transmitters, the important parameter is the cumulative total RF power of all of the transmitters, not the EIRP of any one of them.

B. A single transmitter.

The second issue to be addressed, is that for a given level of RF power (antenna input power) in a real world environment, the interference effect of any one transmitter in an unlicensed band will typically be less as the transmitter antenna gain is increased. The principle reason for this conclusion is that the propagation exponent for real world environments is typically much greater that 2, the propagation coefficient of free space.

For the purpose of this discussion, assume that the propagation exponent is 4, i.e., 12 dB increase in EIRP is required to double distance or range. (In "free space", the RF signal level drops by 6 dB for each doubling of distance, i.e., 6 dB/octave distance.)

Consider Figure C1.

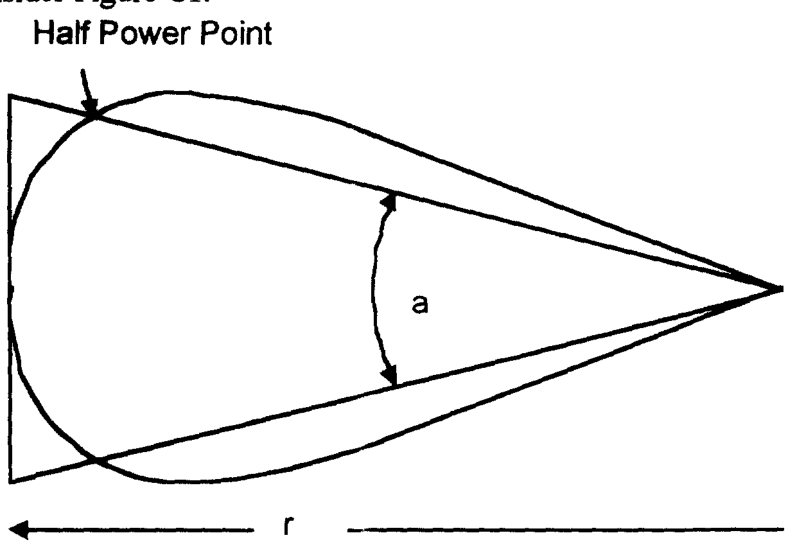


Figure C1

Here a transmitter antenna pattern is illustrated along with a simplified model of the pattern where the half-power beam angle is “a” and the beam length, to some reference signal level, is “r”.

In an unlicensed band, the number of units that might be subjected to harmful interference from the radiated power of a non-interoperable transmitter is proportional to the area of coverage from the non-interoperable transmitter. For this simplified model the pattern area, A_1 is,

$A_1 = a_1 * r_1^2$

Next, assume that the gain the antenna is increased by a numerical factor of 16 (12dB). The angle of the beam is reduced by 16 to a_2

$a_2 = a_1/16$.

The EIRP is increased by the same factor 16, or 12 dB,

Since the propagation exponent is assumed to be 4, the range is increase by a factor of 2, i.e.,

$r_2 = 2 * r_1$

The area of the new pattern is $A_2 = a_2 * (r_2)^2$ and

$A_2 = (a_1/16) * (2 * r_1)^2 = (1/4) * A_1$

Thus, with a propagation coefficient of 4, the area of potential interference is reduced by a factor of 4 if the gain of the antenna is increased by a factor of 16, or 12 dB. Note that if the propagation coefficient was assumed to be 2, as in "free space", the area of coverage with the high gain antenna would be the same as the area of coverage with the lower gain antenna.

Thus, in typical applications, gain antennas actually reduce the total area of interference. and the total number of users subjected to potentially harmful interference will, therefore, be reduced as well.

The proposed antenna gain limit of 23 dB with 1 Watt of power output is based on maintaining an EIRP power spectral density limit, in mWatts per kHz, comparable to that allowed in the 5.8 GHz ISM band. There, DSSS devices may have a minimum bandwidth of only 500 kHz, compared to the expected nominal high data bandwidth of 25 MHz for NII/SUPERNet devices in the 5 GHz band. If there is a need to increase the transmitter antenna gain above 23 dB, Motorola proposes a plan based on the concept the Commission proposed in ET Docket No. 96-8. Specifically, Motorola proposes that the RF power be reduced by 1 dB for each 3 dB increase in antenna gain for antenna gains greater than 23 dB.

CERTIFICATE OF SERVICE

I, Tanya R. Mason, of Motorola Inc. do hereby certify that on this 15th day of July, 1996 a copy of the foregoing "Comments" was sent to each of the following by hand:

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